2. Soil Management, Fertilizer Use, Crop Nutrition and Cover Crops

For a complete guide to soil fertility, consult OMAFRA Publication 611, *Soil Fertility Handbook*.

Crop nutrition is important for the production of high-yielding, top quality fruit crops. Good soil and water management practices are important for a crop's efficient use of nutrients from organic and inorganic fertilizer. Nutrients must be dissolved in the soil water for root uptake. The development of a sound soil fertility program begins with the assessment of nutrient needs.

Assessing Nutrient Needs

There are three ways to assess soil fertility and crop nutrition:

- soil testing
- plant tissue analysis
- visual deficiency symptoms

For perennial crops, all three methods are needed to assess and monitor the crop's nutritional status.

Soil testing

A soil test using methods suited to the soils of a particular region is the best measure of plant-available nutrients. OMAFRA accredits specific laboratory methods suited to Ontario soils (see Table 2–1. *OMAFRA-Accredited Soil Tests* on this page). OMAFRA-accredited laboratories participate in the North American Proficiency Testing Program and must demonstrate their ability to perform these tests accurately.

Soil laboratories may provide additional soil tests not listed in Table 2–1, as well as analyses for greenhouse media, nutrient solutions and water. Testing for soil organic matter can be useful but is not an accredited test. OMAFRA-accredited soil tests are not available for boron, copper, iron or molybdenum. Tissue analysis of these micronutrients is a better indicator of the nutritional status. For other testing services, contact the soil laboratories listed in Appendix F: *Accredited Soil-Testing Laboratories in Ontario*, page 343.

Table 2–1. OMAFRA-Accredited Soil Tests

Nutrient Analyzed	Test
phosphorus	sodium bicarbonate extractable
potassium magnesium	ammonium acetate extractable
manganese	index of soil pH and phosphoric acid extractable manganese
zinc	index of soil pH and DTPA extractable zinc
pH	saturate paste extract
lime requirement	SMP buffer pH
soil nitrate	potassium chloride extraction

When to sample

Always take soil samples before you plant fruit crops. Where pH adjustments are necessary, sample 2 years before planting so that adjustments can be made prior to planting. After establishment, sample each field once every 2 or 3 years. In sandy soils, check soil potassium levels more frequently.

Late summer or fall sampling is ideal for fields to be planted in the spring. For established plantings, soils may be sampled in the summer or fall. Sampling at the same time each year will help with interpreting and comparing results between soil reports. Regardless of when you sample, allow time to mail the samples, receive your report and determine fertilizer requirements.

Taking a soil sample

A soil test report's accuracy and the recommendations depend on proper collection, preparation and submission of a soil sample. To take a soil sample you will need:

- soil probe or shovel
- clean plastic pail (do not use galvanized metal pails because these will contaminate the sample for micronutrient analysis, particularly zinc)
- sample bags and boxes, usually available from the soil laboratory
- a pen or marker

Sample each field or individually managed unit separately. Separate large fields, or fields with considerable variation, into smaller sections. This applies even if the areas are too small to fertilize separately. Each sample should represent a field or field section with similar soil texture, topography, organic matter and crop history. Avoid sampling recent fertilizer bands, dead furrows, areas adjacent to gravel roads, or where lime, manure, compost or crop residues have been piled.

Sample soils using a probe or shovel. Traverse the sampled area in a zigzag pattern to provide a uniform distribution of sampling sites. Take at least 20 soil cores, 15 cm deep, from any field or area sampled up to 5 ha in size. For fields larger than 5 ha, proportionately more cores should be taken. The more cores taken, the more likely the sample will provide a reliable measure of fertility in the field. One sample should not represent more than 10 ha.

Collect the soil in a clean plastic pail. Break up the lumps and mix the soil well, since only about 2 mL of soil from the sample will be used for each analysis. Fill a clean plastic bag with approximately 500 g of soil, place it into the box and forward it for testing. Be sure to clearly mark the sample box with all of the necessary information (sample number, farm name, date, etc.).

Micronutrient deficiencies most often occur in small patches in fields. Problem areas should be sampled separately. When you sample a problem area, be sure to take a comparison sample from an adjacent area without symptoms.

Samples to assess soil nitrogen should be taken by following the same sampling method, except they are taken to a depth of 30 cm. If not submitted immediately, the samples should be stored below 4°C or frozen.

Interpreting soil test results

The OMAFRA-accredited soil-testing program provides recommendations for nitrogen, phosphate, potash, magnesium, zinc and manganese fertilizer. It also gives recommendations for the amount and type of lime to be applied, if required. These recommendations are specific to the future crop to be grown, specified on the lab submission form. Crop-specific details may be found on the following pages:

Apples .... page 27
Berry crops .... page 87
Grapes ....page 159
Tender fruit .... page 183

These recommendations can produce the highest economic yields when accompanied by good or above-average crop management.

On a soil test report, each nutrient is reported in parts per million (ppm) or milligrams per litre (mg/L) of soil, a letter rating and a fertilizer recommendation (usually kg/ha or lb/ac). The letter rating of the nutrient (i.e., high (HR), medium (MR), low (LR), rare (RR) or no response (NR) indicates the likelihood of a profitable response to applied nutrient for the specified crop.

Fertilizer application guidelines depend on the crop. Rates for nitrogen, phosphorus and potassium fertilizers should be adjusted if manure or legume cover crops are incorporated. This information is essential for an optimum fertilizer utilization.

Soil tests from other laboratories

OMAFRA-accredited soil tests are used to provide accurate fertilizer application guidelines. Make certain that the service you use is accredited. To be accredited, a laboratory must use OMAFRA-approved testing procedures to demonstrate acceptable analytical precision and accuracy and must also provide the OMAFRA fertilizer guidelines. Ensure that you ask for the OMAFRA fertilizer guidelines. Soil tests for nutrient management plans must be completed at OMAFRA-accredited labs. Soil tests for exchange capacity, aluminum and copper are not accredited by OMAFRA because they have not been found to contribute to improving fertilizer application guidelines.

Plant tissue analysis

Plant tissue analysis measures the nutrient concentration in plant tissue. It is most useful when combined with visual inspection of the crop and soil conditions, knowledge of past field management and a current soil test to provide information about soil nutrient levels and pH.

For perennial crops, tissue analysis is an important addition to soil tests. Tissue analysis results are compared against established normal ranges for the crop and indicate whether the plant is obtaining adequate nutrients for optimum growth. If soil levels are known to be adequate, low tissue analysis results may indicate there are other possible causes for the nutrient deficiencies. Plant analysis is particularly useful for the evaluation of phosphorus, potassium, magnesium and manganese. It is the main tool for assessing the status of boron, copper, iron and molybdenum, as there is no reliable soil test for these micronutrients.

Sampling

To monitor trends, complete a leaf analysis every year. Sampling the same trees at the same time of the year will assist in interpreting leaf analysis reports from year to year.

Timing and stage of growth when a sample is collected affects the results of plant analysis. Concentrations of some nutrients vary considerably with the age of the sampled tissue and the date of sampling. Results are difficult to interpret if samples are taken at times other than what is optimal for the crop. See Table 2–2. *Sampling for Tissue Analysis of Fruit Crops,* on this page.

- Collect tissue samples into labelled paper bags. Plant tissues will rot if stored in plastic bags.
- Avoid collecting damaged leaves or leaves from plants that appear abnormal.
- Plant tissue should be sampled separately from variable areas large enough to sample soil and fertilize separately.
- Avoid contamination of the sample with soil. Even a small amount of soil will cause the results to be invalid, especially for micronutrients.
- Plants suspected of nutrient deficiency should be sampled as soon as a problem appears. Take tissue samples from a problem area and submit a separate sample from an adjacent, non-affected part of the field. Also collect and submit a soil sample from both affected and non-affected areas to aid diagnosis.

Sample preparation

Fresh plant samples should be delivered directly to the laboratory. If they cannot be delivered immediately, they should be dried to prevent spoilage. Samples may be dried in the sun or in an oven at 65°C or less.

Take precautions to prevent contamination with dust or soil. Avoid contact of samples with brass, copper or galvanized (zinc-coated) metal.

Plant analyses may be obtained from several laboratories in Ontario. Refer to Appendix F: *Accredited Soil-Testing Laboratories in Ontario*, page 343. Tissue analysis is not part of the OMAFRA accreditation program. However, OMAFRA-accredited labs have the necessary skills and equipment to perform accurate tissue analysis.

Interpretation

Tissue analysis has limitations and expert help is sometimes needed to interpret the results. Tissue analysis does not indicate how much fertilizer is required to correct a deficiency or even whether a deficiency is related to soil fertility problems. Tissue test results in the deficiency range may also be due to factors such as climate, pest pressure or disease, and therefore should be used in conjunction with a soil-testing program. Table 2–3. *Nutrient Concentration Sufficiency Ranges for Fruit Crops*, page 12, shows the range of tissue nutrient concentration that should result in optimum productivity for various fruit crops.

Table 2–2. Sampling for Tissue Analysis of Fruit Crops

Crop	Stage of Growth/Timing	Plant Part Sampled	Approximate Number to Collect
Apple	Last 2 weeks of July	Mature mid-shoot leaves of current year growth at shoulder height	10 leaves from 10 representative trees
Blueberry, Highbush	Late July–early August	Mature mid-shoot leaves of current year growth	100 leaves throughout sampling area
Cherry, Montmorency	Last 2 weeks of July	Mature mid-shoot leaves of current year growth at shoulder height	10 leaves from 10 representative trees
Grape	Early September	Petioles from mature leaves of fruiting canes – remove from leaf immediately	75–200 depending on variety size
Peach	Last 2 weeks of July	Mature mid-shoot leaves of current year growth at shoulder height	10 leaves from 10 representative trees
Pear	Last 2 weeks of July	Mature mid-shoot leaves of current year growth at shoulder height	10 leaves from 10 representative trees
Raspberry	Late July	Fully expanded leaves from fruiting cane	100 throughout sampling area
Strawberry	Fruiting – June Non fruiting – early August	Fully expanded, recently matured leaf – discard petiole immediately	50 leaves throughout sampling area

Table 2–3. Nutrient Concentration Sufficiency Ranges for Fruit Crops

	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Iron	Boron	Zinc	Manganese
Crop	%					ppm			
Apples[1]									
Delicious, Crispin	2.2–2.7	0.15–0.4	1.4–2.2	0.8–1.5	0.25–0.4	25–200	20–60	15–100	20–200
Empire, Spy	2.1–2.6	0.15–0.4	1.3–2.1	0.7–1.5	0.25–0.4	25–200	20–60	15–100	20–200
McIntosh, Others	2–2.5	0.15–0.4	1.2–2	0.8–1.5	0.25–0.4	25–200	20–60	15–100	20–200
Berry Crops									
Blueberry, Highbush	1.7–2.3	0.15–0.4	0.36–0.7	0.3–0.8	0.12–0.3	30–100	15–50	10–100	150–500
Raspberry	2–3.5	0.20–0.5	1–2	0.8–2.5	0.25–0.5	25–200	20–60	15–100	20–200
Strawberry	2–3	0.20–0.5	1.5–2.5	0.5–1.5	0.25–0.5	25–200	20–60	15–100	20–200
Grapes (Petioles)									
Vinifera	0.8–1.4	0.15–0.4	1.2–2.3	1–3	0.6–1.5	15–100	20–60	15–100	20–200
Fredonia	0.6–1.2	0.15–0.4	0.8–1.8	1–3	0.6–1.5	15–100	20–60	15–100	20–200
Other	0.7–1.3	0.15–0.4	1–2	1–3	0.6–1.5	15–100	20–60	15–100	20–200
Tender Fruit									
Peach	3.4–4.1	0.15–0.4	2.3–3.5	1–2.5	0.35–0.6	25–200	20–60	15–100	20–200
Pear	2–2.6	0.15–0.4	1.2–2	1–2	0.25–0.5	25–200	20–60	15–100	20–200
Plum	2.4–3.2	0.15–0.4	1.5–3	1–2.5	0.35–0.65	25–200	20–60	15–100	20–200
Cherry, Montmorency	2.2–3	0.15–0.4	1.3–2.5	1–2.5	0.35–0.65	25–200	20–60	15–100	20–200

[1] Leaf nitrogen should be 0.2% higher for apple trees on M.9 or M.26 rootstocks and for all non-bearing trees.

Visual deficiency symptoms

Leaf symptoms can help evaluate some nutrient deficiencies, but have limitations. By the time deficiency symptoms are visible, yield losses may already have incurred. Visual deficiency symptoms are easily confused with other production problems such as pesticide injury, leaf and root diseases, nematodes, insect damage, compaction or air pollution. Suspected visual deficiencies should always be confirmed by tissue analysis. Specific nutrient deficiency symptoms are described in *Apple Nutrition*, page 27, *Berry Crop Nutrition*, page 87, *Grape Nutrition*, page 159 and *Tender Fruit Nutrition*, page 183.

Soil Organic Matter

Soil organic matter helps maintain soil structure, enhances soil moisture-holding capacity, increases the ability of the soil to hold nutrients and improves drainage. Adequate soil organic matter levels can help maintain crop yields and long-term plant health, especially in adverse weather conditions. Many horticultural soils are light-textured and frequently cultivated. The maintenance of organic matter levels in these soils is a challenge but critical to maintain productivity.

To ensure long-term productivity of fruit crops, assess the soil quality of each field before planting and take steps to maintain or improve it. For more information, see OMAFRA Publication 611, *Soil Fertility Handbook* and Table 2–4. *Optimum Organic Matter Content for Soil Types* on this page. See also *Cover Crops and Building a Healthy Soil*, page 23.

Table 2–4. Optimum Organic Matter Content for Soil Types

Soil Type	Optimum Organic Matter (%)
Sandy	2–4 +
Sandy loam	3–4 +
Loam	4–5 +
Clay loam	4–5 +
Clay	4–6 +

Source: The Canada-Ontario Environmental Farm Plan Program *Workbook*, 3rd ed., 2004.

Soil pH and Liming

The pH scale ranges from 0–14 and is a measure of the hydrogen ion concentration. A pH value of 7.0 is neutral. Values below 7.0 are acidic. Those above 7.0 are alkaline, also called basic. On mineral soils, most fruit crops grow well in a soil pH range from 6.0–7.5.

Blueberries require a range of 4.2–5.0. Maintenance of a soil within the appropriate pH range is important. Many crop nutrients, especially micronutrients, become less available at a soil pH above or below the ideal range. At a soil pH less than 5.0, levels of aluminium and manganese may be toxic for sensitive crops.

Raising pH

Soil pH is increased through the broadcast and incorporation of ground limestone into the soil. The amount of lime needed is determined by the soil test results. Table 2–5. *Soil pH and Liming Guidelines for Fruit Crops*, on this page, shows pH values below which lime is needed, and the target soil pH to which soils should be limed. In Ontario, most crops grow quite well at pH values higher than the target pH. If lime is required, apply it at least one year before planting.

Table 2–5. Soil pH and Liming Guidelines for Fruit Crops

Fruit crops	Soil pH below which lime is suggested	Target soil pH
Coarse- and Medium-Textured Mineral Soils (sands, sandy loams, loams and silt loams)		
All fruit crops not listed below	6.1	6.5
Established tree fruits, grapes	5.6	6.0
Blueberry, cranberry	No lime needed	
Fine-Textured Mineral Soils (clays and clay loams)		
All fruit crops not listed below	5.6	6.0
Established tree fruits, grapes	5.1	5.5
Blueberry, cranberry	No lime needed	
Organic Soils (peats and mucks)		
All fruit crops not listed below	5.1	5.5
Blueberry, cranberry	No lime needed	

Buffer pH

The soil pH measures the amount of acidity in the soil solution, indicating whether liming is necessary for crop production. It does not measure the amount of reserve acidity held on the clay and organic matter particles in the soil, which determines how much lime is needed. Different amounts of reserve acidity will mean that two different soils at the same pH value will need different amounts of lime to raise the pH to the desired level. The reserve acidity is measured in a separate test called the buffer pH. A soil with high reserve acidity will have a low buffer pH and will require considerable lime to raise the pH.

To determine the amount of lime required to reach the target soil pH, use Table 2–6. *Lime Requirements to Correct Soil Acidity* on this page.

Table 2–6. Lime Requirements to Correct Soil Acidity

Buffer pH	Ground Limestone Required (tonne/ha)*			
	Target soil pH = 7.0[1]	Target soil pH = 6.5[2]	Target soil pH = 6.0[3]	Target soil pH = 5.5[4]
7.0	2	2	1	1
6.9	3	2	1	1
6.8	3	2	1	1
6.7	4	2	2	1
6.6	5	3	2	1
6.5	6	3	2	1
6.4	7	4	3	2
6.3	8	5	3	2
6.2	10	6	4	2
6.1	11	7	5	2
6.0	13	9	6	3
5.9	14	10	7	4
5.8	16	12	8	4
5.7	18	13	9	5
5.6	20	15	11	6
5.5	20	17	12	8
5.4	20	19	14	9
5.3	20	20	15	10
5.2	20	20	17	11
5.1	20	20	19	13
5.0	20	20	20	15
4.9	20	20	20	16
4.8	20	20	20	18
4.7	20	20	20	20
4.6	20	20	20	20

* Based on Agricultural Index of 75.
[1] Liming to pH 7.0 is recommended only for club-root control on cole crops.
[2] Add lime if soil pH is below 6.1.
[3] Add lime if soil pH is below 5.6.
[4] Add lime if soil pH is below 5.1.

The lime requirements listed in Table 2–6 are based on the equations in Table 2–7. *Calculation of Lime Required*, on this page, and rounded to the nearest tonne/ha. More exact requirements to adjust soil pH to 7.0 may be calculated from the equations in Table 2–7.

Table 2–7. Calculation of Lime Required

Target Soil pH	Equation*
7.0	Lime (tonne/ha) = $334.5 - 90.79\ pH_B^{**} + 6.19\ pH_B^2$
6.5	Lime (tonne/ha) = $291.6 - 80.99\ pH_B + 5.64\ pH_B^2$
6.0	Lime (tonne/ha) = $255.4 - 73.15\ pH_B + 5.26\ pH_B^2$
5.5	Lime (tonne/ha) = $37.7 - 5.75\ pH_B$

* Based on lime with an Agricultural Index of 75.
** pH_B = Buffer pH.

Raising the soil pH with limestone

Either calcitic or dolomitic limestone can be applied to raise soil pH. Calcitic limestone consists largely of calcium carbonate, while dolomitic limestone is a mixture of both calcium and magnesium carbonates. The carbonate in the limestone neutralizes the soil acidity.

Use dolomitic limestone on soils with a magnesium soil test of 100 ppm or less. It is particularly important to use dolomitic limestone when the level of potassium is high because high potassium levels make magnesium deficiency more likely. Either calcitic or dolomitic limestone can be used when magnesium test results are greater than 100 ppm and potassium levels are below 250 ppm.

Limestone varies in its effectiveness for raising soil pH depending on its neutralizing value and its fineness rating.

Neutralizing value is the amount of acid a given quantity of limestone will neutralize when it is totally dissolved. It is expressed as a percentage of the neutralizing value of pure calcium carbonate. Limestone that will neutralize 90% as much acid as pure calcium carbonate is said to have a neutralizing value of 90. In general, the higher the calcium and magnesium content of a limestone, the higher the neutralizing value.

Fineness rating, or particle size, also affects the neutralizing value of limestone. The higher the fineness rating, the more rapidly the limestone raises the soil pH.

The Agricultural Index

The Agricultural Index combines the neutralizing value and the fineness rating of a limestone. It provides a way to compare different limestone sources. Limestone with a high Agricultural Index is applied at a lower rate than limestone with a low index. A limestone's Agricultural Index is determined by the following formula:

$$\text{Agricultural Index} = \frac{\text{neutralizing value} \times \text{fineness rating}}{100}$$

Limestone recommendations from the OMAFRA-accredited soil tests are based on limestone with an Agricultural Index of 75. When you use a limestone source with a different Agricultural Index, a specific rate of application may be calculated with the following equation:

$$\text{Limestone application rate from soil test} \times \frac{75}{\text{Agricultural Index of the limestone source being used}} = \text{Rate of application of the limestone source being used}$$

For example, if a soil test recommends 9 tonnes/ha of limestone and the limestone source has an Agricultural Index of 90, the application rate should be 7.5 tonnes/ha (9 × 75/90 = 7.5 tonnes/ha).

The Agricultural Index does not provide information about magnesium content.

Effect of tillage depth

The lime application rates presented in Table 2–6. *Lime Requirements to Correct Soil Acidity*, page 13, should raise the pH of the top 15 cm of soil to the listed target pH. If the soil is plowed to a lesser or greater depth than 15 cm, proportionately more or less lime is required to reach the same target pH. Where shallow tillage depths are used, more frequent applications of lower rates are suggested.

Lowering pH

On soils with pH values below 6.5, it is possible to lower the pH (make the soil more acidic) by adding sulphur or ammonium sulphate. This may be desirable for some crops, such as blueberries, but usually will not be suitable for rotation crops. Soil pH cannot be adjusted up or down from year to year. Ammonium sulphate should not be applied at rates of nitrogen higher than those recommended for the current crop. Table 2–8. *Sulphur for Soil Acidification*, on this page, shows the amount of elemental sulphur required to lower the pH of various soils.

If the soil pH is above 6.5, it is not advisable and also usually quite impractical to lower the soil pH because of the very large amounts of sulphur or ammonium sulphate required. For more information see OMAFRA Publication 611, *Soil Fertility Handbook* (Soil Acidification, page 94).

Table 2–8. Sulphur for Soil Acidification

Soil Type	Sulphur Required (kg/ha)	
	For each 1.0 pH unit	For each 0.1 pH unit
Sand	350	35
Sandy loam	750	75
Loam	1,100	110

Nitrogen

Nitrogen is an important element for the growth and development of all plants, and is naturally present in all soils. As soil microbes feed on crop residues and soil organic matter, they release nitrogen into the soil. As soil organic matter levels increase, so do the levels of naturally available nitrogen. Management practices which maintain and increase soil organic matter will also help to enhance soil fertility and crop productivity. Legumes, such as alfalfa and red clover, can increase soil nitrogen concentrations by capturing atmospheric nitrogen and releasing it slowly into the soil.

Visual nitrogen deficiency symptoms

Nitrogen deficiencies usually first appear on older leaves. These leaves will turn light green or yellow as nitrogen is relocated from older, less productive leaves to the newest growth. Cool temperatures in early spring often cause plants to develop a temporary nitrogen deficiency. This is usually due to poor growing conditions, and not necessarily a lack of nitrogen in the soil.

Nitrogen and the environment

Nitrogen levels in the soil change constantly. Processes like leaching and denitrification result in the loss of nitrogen from the soil. Denitrification occurs when the soil is waterlogged. Anaerobic microbes convert nitrate and ammonia into nitrous oxide. This gas can contribute to air pollution and is approximately 300 times more potent than carbon dioxide as a greenhouse gas.

The nitrate form of nitrogen, while being readily available to plants, moves easily in water through the soil. As a result, it has the potential to pollute groundwater and surface water.

Applying just enough nitrogen to meet the crop's growth requirements greatly reduces the risk of loss to the environment. The potential for nitrogen loss is highest during the late fall and early spring. Applying nitrogen according to the crop's need reduces residual soil nitrogen at the end of the season and leaves little available for losses.

It is important to account for fertilizer, manure and other sources of nitrogen when you assess a crop's fertility requirements. Other management practices to reduce the risk of nitrate losses include:

- use of cover crops
- timing nitrogen applications close to crop nitrogen uptake
- reduction of total nitrogen applications

Sources of nitrogen

Synthetic fertilizer

The most common nitrogen fertilizer sources are outlined in Table 2–9. *Fertilizer Materials: Primary Nutrients* on this page. Generally, all nitrogen sources are effective in providing a crop with nitrogen. Cost, crop management and ease of application will largely determine the selection of one source over another.

If nitrogen is to be applied early in the spring when soils are below 10°C, using urea may prevent leaching losses. Under these conditions, it takes 3–6 weeks for urea to convert to the plant-available ammonium and nitrate forms. As only nitrate-nitrogen is susceptible to leaching losses, early spring rain will not result in leaching where urea is used as the nitrogen source. By the time the nitrate conversion has occurred, the crop is entering its rapid growth phase and minimal downward percolation of water will make leaching less likely.

Table 2–9. Fertilizer Materials: Primary Nutrients

Nitrogen Materials	Form	% Nitrogen (N)
Ammonium nitrate	dry	34
Ammonium sulphate	dry	20
Calcium ammonium nitrate	dry	27
Calcium nitrate	dry	15.5
Urea	dry	46
Anhydrous ammonia	liquid[1]	82
Urea ammonium nitrate (UAN)	liquid	28–32
Phosphate Materials	**Form**	**% Phosphate (P_2O_5)**
Diammonium phosphate (18-46-0)	dry	46
Monoammonium phosphate (11-52-0)	dry	50–52
Single superphosphate	dry	20
Triple superphosphate	dry	46
Ammonium polyphosphate (10-34-0)	liquid	34
Potash Materials	**Form**	**% Potash (K_2O)**
Muriate of potash	dry	60–62
Potassium nitrate (13-0-44)	dry	44
Sulphate of potash	dry	50
Sulphate of potash magnesia (11% Mg)	dry	22

[1] Liquid under pressure.

Products that modify the release of nitrogen

Slow-release fertilizers have granules that have been coated in sulphur or a polymer to control the release of the nitrogen over an extended period of time. Nitrification inhibitors are added to nitrogen fertilizers to help delay the chemical conversion of urea into the plant-available forms. Depending on the weather conditions, the delayed release of these products may not necessarily coincide with peak nitrogen demand.

Manure nitrogen

In addition to nutrients and micronutrients, manure also supplies valuable organic matter that helps to build and maintain soil structure. Adjust fertilizer rates to account for the nutrients in manure.

During the first growing season after application, 50%–60% of the nitrogen in manure is available to the crop. The remaining organic nitrogen becomes available in small, diminishing quantities in successive years. Up to 10% of the total nitrogen in manure can be available for the following year. Where manure is applied regularly to the same field, there may be a significant amount of residual nitrogen available for a crop.

The quantities of nutrients contained in manure can vary greatly. The type of livestock, ration, bedding, added liquids and storage system all affect the final nutrient analysis. Table 2–10. *Average Fertilizer Replacement Values for Manure*, on this page, provides the approximate amount of crop-available nitrogen in manure. A manure analysis, available from several laboratories in Ontario, provides the most accurate assessment of the nutrients contained in a specific source of manure. Refer to Appendix F: *Accredited Soil-Testing Laboratories in Ontario*, page 343, for a list of laboratories providing this service.

Use manure responsibly

- Avoid the spread of manure on frozen or snow-covered ground.
- Avoid application when the potential for runoff (soil is wet, rain is imminent, etc.) is high.
- Tillage prior to the application of liquid manure will help to break up soil cracks and large pores, and prevent the movement of manure into field tiles or shallow groundwater.
- Inject or incorporate the manure to minimize loss of ammonia to the atmosphere.
- When storing manure, follow guidelines in OMAFRA Factsheet, *Temporary Field Storage of Solid Manure or Other Agricultural Source Materials*.

Manure and food safety

Fruit can become contaminated in the field if it comes into contact with pathogens that cause human illness. These pathogens may come from manure and manure-based composts. Depending on conditions, these pathogens can survive from 1 to more than 300 days after field application of fresh manure. Pathogens can be reduced to acceptable levels when manure is properly composted. Proper composting means that all parts of the manure pile must heat to 55°C for 3 days to reduce pathogen levels. Fresh or uncomposted manure should not be applied to fields where fruit or vegetable crops will be harvested within 120 days.

Table 2–10. Average Fertilizer Replacement Values for Manure

Nutrient values are based on average analysis for over 3,000 samples.[1] There are large variations in nutrient content between manures, so a manure analysis is your best guide to nutrient availability.

Manure	% Average Dry Matter	Available[2] Nitrogen (N)	Available[3] Phosphate (P_2O_5)	Available[4] Potash (K_2O)
Liquid Manure		**kg/1,000 L (lb/1,000 gal)**		
Liquid dairy	8.6	1.8 (18)	0.8 (8.3)	2.7 (27)
Liquid hog	3.6	2.5 (25)	1.1 (11)	2.1 (21)
Liquid poultry	10.0	4.7 (47)	2.6 (26)	3.2 (32)
Dry Manure		**kg/tonne (lb/ton)**		
Solid poultry	60.6	15.9 (32)	12.1 (24)	15.7 (31.4)
Solid dairy	25.9	2.6 (5.2)	1.8 (3.7)	6.6 (13.2)
Composted dairy	38.3	2.2 (4.5)	2.6 (5.2)	11.1 (23.8)
Solid beef	31.4	3.6 (7.3)	3.0 (6.1)	7.1 (14.3)
Sheep	32.2	2.8 (5.5)	3.1 (6.3)	8.2 (16.4)
Horse	37.4	0 (0)	1.4 (2.8)	4.6 (9.3)

[1] Data from manure analysis provided from Ontario labs collected between 1992 and 2012.
[2] Nitrogen based on spring application, incorporated within 24 hours. Unincorporated manure will have less N due to ammonia losses.
[3] Phosphate from manure or biosolids is assumed to be 40% as available in the year of application as that in commercial fertilizer (another 40% of the phosphorus is available the following year).
[4] Potassium from manure is assumed to be 90% as available in the year of application as that in commercial fertilizer.

Legumes

Rhizobium bacteria infect the roots of legume crops. These bacteria convert atmospheric nitrogen into inorganic nitrogen. As the legume crop residue decomposes, this nitrogen becomes available for subsequent crops. When fruit crops are planted following alfalfa hay, or a legume cover crop such as red clover, the rate of fertilizer nitrogen should be decreased according to Table 2–11. *Nitrogen Contribution of Plowed-Down Legumes* on this page.

Table 2–11. Nitrogen Contribution of Plowed-Down Legumes

Type of sod	For all crops, deduct from N requirement (kg N/ha)
Less than ⅓ legume	0
⅓ to ½ legume	55
½ or more legume	100
Perennial legumes seeded and plowed the same year	45[1]
Soybean and field bean residue	0

[1] Applies where the legume stand is thick and over 40 cm high.

Other organic nutrient sources

Biosolids derived from paper mill fibre have been used in orchards and vineyards to maintain soil organic matter. However, before this material can be applied to land, you must have an Environmental Compliance Approval (ECA) issued by the Ministry of the Environment and Climate Change (MOECC) for the site. Rates depend upon the nitrogen content of the material and can be in the range of 25–30 dry tonnes/ha. However, MOE has final approval of the material and the applied rate. Any application restrictions are included as conditions on the ECA.

Biosolids from sewage treatment plants or paper mill waste can be a useful source of nutrients and organic matter. Guidelines for their use are available from OMAFRA and MOECC. An ECA for land application is required and is available from MOECC. An analysis of nutrients applied should be given by the applicator to the landowner whenever biosolids are applied. Always consult with your processor, packer or broker before applying municipal sewage biosolids on ground intended for vegetables anywhere in the rotation.

Municipal sewage biosolids must not be applied to tree fruits or grapes within three months of harvest. For small fruit (strawberries, raspberries and blueberries), application may not occur within 15 months of harvest.

Avoid fertilizer burn!

Like all inorganic fertilizers, nitrogen and potash fertilizers are salts. If a germinating seedling or young transplant comes into contact with a concentrated fertilizer band, the tender roots may become seriously damaged. For this reason, it is important to ensure that the correct fertilizer and the appropriate rate are selected for each application.

Urea is an effective, economical source of nitrogen for broadcast applications but it has a relatively high salt index. It is not suitable for use in starter fertilizers or banded applications. If low soil moisture conditions exist at the time of planting, urea burn may occur on coarse sandy loam soils and growers should consider switching to a different nitrogen source. Anhydrous ammonia also has a relatively high salt index. It is an effective source for side-dress applications that must be injected into the soil.

Ensure that starter or transplant fertilizers contain only as much nitrogen as necessary to get the crop started. Fertilizers that contain more than half as much nitrogen as phosphate frequently contain urea and may cause crop damage.

Phosphorus

Like nitrogen, phosphorus is important to photosynthesis and the development of enzymes and protein. It also plays a major role in cell division and the synthesis and transport of sugars and starches.

Soil phosphorus levels across Ontario are variable. Because phosphorus, as orthophosphate, tends to bind to soil particles, leaching through the soil profile is minimal. Many coarse sandy loam soils often contain high phosphorus levels. Soils with a history of regular manure applications have high levels of phosphorus, and fruit crop yield will rarely respond to additional phosphorus fertilizer. Too much phosphorus can induce deficiencies of zinc and iron.

Visual phosphorus deficiency symptoms

Phosphorus deficiency symptoms usually develop on the older leaves first. The leaves develop a purplish-red colour that may be more noticeable on the underside of the leaves. Severe deficiencies may also cause the leaf tips to die back. Cool, wet soil conditions often induce phosphorus deficiencies. During establishment of early-planted fruit crops, use a starter fertilizer to deliver the required phosphorus directly to the root zone.

Phosphorus in the environment

Surface runoff is the main route by which phosphorus leaves the field and contaminates the environment. It can be transported in solution with runoff water or through its attachment to eroded soil particles. When this water reaches open surface water, streams can become polluted.

Avoid additional phosphorus applications to soils that are rated Rare Response (RR) or No Response (NR). If phosphorus is required to promote early season growth, use low rates applied in a band close to the roots or as a starter fertilizer.

Farmers who are required to complete a nutrient management plan must establish a permanent vegetative buffer adjacent to any surface water, with a minimum width of 3 m, prior to any nutrient application. This practice is highly recommended even in situations where it is not a requirement. The grass will help reduce erosion and act as a natural filter for runoff entering the watercourse.

Where phosphorus soil tests are greater than 30 ppm, use the Phosphorus Index to determine separation distances from surface water sources. The Phosphorus Index uses factors such as field slope, length of slope, soil drainage class and soil texture to determine an appropriate rate and separation distance for phosphorus application from surface water. For details, see OMAFRA Factsheet, *Determining the Phosphorus Index for a Field*.

More information on best management practices for reducing phosphorus from agriculutral sources can be found in *A Phosphorus Primer* available through Service Ontario at www.publications.serviceontario.ca.

Sources of phosphorus

Mineral fertilizers

The most common phosphate fertilizer sources are outlined in Table 2–9. *Fertilizer Materials: Primary Nutrients*, page 15.

Manure

When properly applied, manure is an excellent, inexpensive phosphorus source. It also supplies the soil with valuable organic matter and micronutrients. Table 2–10. *Average Fertilizer Replacement Values for Manure*, page 16, provides the approximate amount of crop-available phosphorus contained in manure.

Unlike nitrogen, the phosphorus in manure becomes available to crops over a considerable period of time. Regular manure applications may result in a build-up of soil phosphorus, which should be monitored with a soil-testing program.

Manure can pose a food safety risk on many fruit crops. Ensure at least 120 days between manure application and harvest.

Phosphorus application methods

Phosphorus is relatively immobile in the soil, therefore, broadcasting and incorporating any required phosphorus prior to planting perennial fruit crops is crucial. Some phosphorus is often applied at planting in a band or in transplant solution to ensure good vigour of new plantings. On established perennial crops, it can be broadcast on the surface or banded near the roots. Do not rely on fertigation for phosphorus application.

Phosphorus requirements

Use a soil test from an OMAFRA-accredited lab in conjunction with Table 2–12. *Phosphorus Requirements for Fruit Crops* on this page. For crop-specific details see: *Apple Nutrition*, page 27, *Berry Crop Nutrition*, page 87, *Grape Nutrition*, page 159, and *Tender Fruit Nutrition*, page 183.

Table 2–12. Phosphorus Requirements for Fruit Crops

	New plantings of blueberries, strawberries, raspberries, gooseberries, currants, nursery stock	Established blueberries, strawberries, raspberries, gooseberries, currants, nursery stock	New plantings[1] of apples, peaches, pears, plums, cherries, grapes
Soil phosphorus (ppm)*	**Phosphate (P_2O_5) required (kg/ha) [response rating]**		
0–3	140 [HR]	100 [HR]	80 [HR]
4–5	130 [HR]	90 [HR]	60 [HR]
6–7	120 [HR]	80 [HR]	50 [HR]
8–9	110 [HR]	70 [HR]	40 [MR]
10–12	100 [HR]	70 [HR]	20 [MR]
13–15	90 [HR]	60 [HR]	0 [LR]
16–20	70 [MR]	50 [MR]	0 [LR]
21–25	60 [MR]	40 [MR]	0 [RR]
26–30	50 [MR]	30 [MR]	0 [RR]
31–40	40 [MR]	20 [MR]	0 [RR]
41–50	0 [LR]	0 [RR]	0 [RR]
51–60	0 [RR]	0 [RR]	0 [RR]
61–80	0 [NR]	0 [NR]	0 [NR]
80+	0 [NR]	0 [NR]	0 [NR]

HR, MR, LR, RR, and NR denote, respectively: high, medium, low, rare and no probabilities of profitable crop response to applied nutrient.

* 0.5 M sodium bicarbonate extract test method.

[1] For established tree fruits and grapes, plant analysis is used to estimate requirements.

Potassium

Potassium is an important component of plant cells. It also influences the uptake of water by the roots and plays a role in both respiration and photosynthesis. The sugar and starch content of crops like potatoes and tomatoes may be affected by potassium levels. Most crops require equal amounts of potassium and nitrogen.

Visual potassium deficiency symptoms

Potassium deficiency usually appears on the older leaves first. It can cause yellowing or burning of leaf margins.

Sources of potassium

Mineral fertilizers

The most common potassium sources are outlined in Table 2–9. *Fertilizer Materials: Primary Nutrients*, page 15.

Manure

Manure is an excellent, inexpensive source of potassium. It also supplies the soil with valuable organic matter and micronutrients. Table 2–10. *Average Fertilizer Replacement Values for Manure*, page 16, provides the approximate amount of crop-available potash contained in manure.

Unlike nitrogen, the potassium found in manure can be held by the soil over a considerable period of time. Regular application of manure over time may result in a build-up of potassium which should be monitored with a soil-testing program.

Manure can pose a food safety risk on many fruit crops. Ensure at least 120 days between manure application and harvest.

Potassium application methods

The mobility of potassium fertilizers is limited and falls between that of nitrogen and phosphorus. It is not prone to leaching losses, with the possible exception of very sandy soils low in organic matter. Potash should be broadcast and incorporated prior to planting. In drip irrigation systems, up to half of the potassium requirement can be applied through fertigation after crop establishment. At least half of the potassium should be applied in the spring as a broadcast, band in the drip-line of the crop, or in the herbicide strip. Potassium can be blended with nitrogen and applied in one application.

Foliar applications can be made in grapes and should be considered in dry years when soil uptake is reduced. Foliar application at veraison may improve yield of grapes.

Potassium requirements

Use a soil test from an OMAFRA-accredited lab in conjunction with Table 2–13. *Potassium Requirements for Fruit Crops* on this page. For crop-specific details see: *Apple Nutrition*, page 27, *Berry Crop Nutrition*, page 87, *Grape Nutrition*, page 159, and *Tender Fruit Nutrition*, page 183.

Excessive potassium applications reduce a crop's ability to take up magnesium from the soil. Where potassium levels are high, magnesium deficiencies are more likely to occur, particularly if magnesium levels are already low.

Potassium is important for fruit colour, winter hardiness, tree growth and disease resistance in tree fruits. In apples and tender fruits, do not exceed 3 kg of potash per tree even in cases of severe deficiency.

Do not use muriate of potash (0-0-60) in blueberries, currants and gooseberries due to their sensitivity to chloride.

Table 2–13. Potassium Requirements for Fruit Crops

	New or established blueberries, strawberries, raspberries, gooseberries, currants, nursery stock	New plantings of apples, peaches, pears, plums, cherries[1]	New plantings of grapes[1,2]
Soil potassium (ppm)*	**Potash (K_2O) required (kg/ha) [response rating]**		
0–15	130 [HR]	180 [HR]	270
16–30	120 [HR]	170 [HR]	270
31–45	110 [HR]	160 [HR]	270
46–60	100 [HR]	140 [HR]	270
61–80	90 [HR]	110 [HR]	270
81–100	80 [HR]	70 [MR]	270
101–120	70 [MR]	40 [MR]	270
121–150	60 [MR]	20 [MR]	270
151–180	40 [MR]	0 [LR]	270
181–210	0 [LR]	0 [LR]	270
211–250	0 [RR]	0 [RR]	270
250+	0 [NR]	0 [NR]	270

* 1 M ammonium acetate extract test method.

[1] For established tree fruits and grapes, plant analysis is used to estimate requirements.
[2] Apply only every second year.

Calcium

Calcium is a vital component of cell walls and is involved in the metabolism and formation of the cell nucleus. Calcium pectate in the cell walls provides a physical barrier to disease entry. Calcium does not move readily within the plant.

Calcium deficiencies may cause the growing point to die. It may also cause the blossoms and buds to drop prematurely. However, calcium deficiencies rarely occur in fruit crops grown on soils with a pH of 6.0–7.5. On coarse sandy loam soil, with acidic or low pH, additional soil or foliar calcium may be required. Refer to Table 2–14. *Calcium, Magnesium and Micronutrient Sources* on this page.

Calcium-related disorders may occur in some crops, for example tip burn in strawberries, gummosis in plums, and bitter pit in some apple varieties. Several management practices will reduce the occurrence of calcium-related disorders. Avoiding over-application of nitrogen will help prevent excessive vegetative growth which can dilute the calcium in the plant. Good soil management practices ensure good root growth, which will promote both water and nutrient uptake. Timely irrigation will help keep calcium moving into the plant.

Foliar applications of calcium can be made to reduce the incidence of bitter pit in apples, gummosis in European plums, stem and bunch breakdown in certain varieties of grapes and various problems in pears. Because of the potential for leaf burn and premature ripening with foliar-applied calcium, only apply if a problem is anticipated. For crop-specific details, see: *Apple Nutrition*, page 27, *Grape Nutrition*, page 159 and *Tender Fruit Nutrition*, page 183. Do not concentrate sprays or leaf burn could occur. To avoid adverse effects on fruit quality and storability, do not apply calcium formulations containing nitrogen beyond the end of July unless correcting a nitrogen deficiency. Consult OMAFRA Factsheet, *Bitter Pit Control in Apples*.

Table 2–14. Calcium, Magnesium and Micronutrient Sources

A number of micronutrients are available as chelates, with various formulations and nutrient contents. Check the product labels for crop-specific recommendations. The effective use rate for chelated products is the same as for other formulations. ✓ indicates that it can be applied to the soil or as a foliar spray.

Nutrient	Source	% Nutrient	Other Nutrients	Application	
				Soil	Foliar
Calcium (Ca)	calcitic limestone	22–40	—	✓	—
	calcium chloride	36	64% chloride	✓	✓
	calcium nitrate	19	15.5% nitrogen	✓	✓
	calcium sulphate (gypsum)	23	19% sulphur	✓	—
	dolomitic limestone	16–22	6%–13% magnesium	✓	—
	pelletized lime	16–40	0%–13% magnesium	✓	—
Magnesium (Mg)	dolomitic limestone	6–13	16%–22% calcium	✓	—
	epsom salts	9	13% sulphur	✓	✓
	sulphate of potash magnesia	11	22% potash K_2O 20% sulphur	✓	—
Boron (B)	sodium borate	12–21	—	✓	✓
	solubor	20	—	—	✓
	various granular materials	12–15	—	✓	—
Copper (Cu)	copper chelates	5–13	—	—	✓
	copper sulphate	13–25	6.5–12.5% sulphur	✓	—
Iron (Fe)	ferrous sulphate	20	11% sulphur	—	✓
	iron chelates	3–13	—	—	✓
Manganese (Mn)	manganese chelates	5–12	—	—	✓
	manganese sulphate	28–32	16%–18% sulphur	—	✓
Molybdenum (Mo)	sodium molybdate	39	—	—	✓
Zinc (Zn)	zinc chelates	9–14	—	—	✓
	zinc oxysulphate	8–36	—	✓	—
	zinc sulphate	36	17% sulphur	✓	✓

Magnesium

Magnesium is an essential part of chlorophyll and aids in the formation of sugars, oils and fats.

Magnesium is mobile within the plant. Deficiencies usually appear on the older leaves first as it is translocated to the younger leaves. The leaf tissue between the veins turns yellow, while the veins remain green. Severe deficiencies will cause the leaf margins to curl. In apples, magnesium deficiency can cause premature fruit drop, especially with McIntosh. A foliar spray will correct magnesium deficiency in the current year only, and should be combined with soil application for a longer term solution.

In conjunction with an OMAFRA-accredited magnesium soil test, consult Table 2–15. *Magnesium Management in Soil for Fruit Crops*, on this page.

Excessive potassium applications can induce a magnesium deficiency, therefore avoid using high rates of potash on soils with a low magnesium rating.

Micronutrients

Micronutrients include boron, copper, iron, manganese, molybdenum and zinc. Plants use these elements in much smaller amounts than macronutrients (nitrogen, phosphorus, potassium, calcium and magnesium). Because such small quantities are required, routine application is generally an unnecessary expense. However, micronutrients are crucial to growth and deficiencies must be corrected.

Micronutrients are usually found in much lower levels in the soil than macronutrients. Soil pH, organic matter, clay and mineral content can strongly influence micronutrient availability. This makes soil tests for estimating micronutrient availability less reliable than those for the primary nutrients.

Which to choose: soil or foliar fertilizers?

Both soil and foliar fertilizers play a role in fruit crop production. The macronutrients are required in relatively high amounts for crop growth. As a result, soil application is almost always the most efficient and economical method of getting these nutrients into the plant. Foliar uptake occurs through the leaf's cuticle and the stomata. The amount of nutrients that can enter the plant through these means is quite limited. Higher application rates may lead to crop injury.

Since micronutrients are required in much lower quantities, they can often be efficiently delivered through foliar applications, especially when soil conditions limit micronutrient availability. If a micronutrient deficiency is found, foliar application is the quickest way of addressing it. This can be followed with a soil application to prevent a recurrence, depending on the micronutrient and the soil pH.

Do not apply micronutrients to fruit crops unless a deficiency is identified. Apply only the deficient nutrient in sufficient quantities to correct the problem. The range between deficiency and toxicity with micronutrients can be narrow.

Use caution when you apply mixtures of several micronutrients, as crop injury may occur. Always follow the product label. Do not combine micronutrients with insecticides, fungicides or herbicides unless there is information from the manufacturers that indicates the components are compatible. Many chelated micronutrients will consolidate in the spray tank if mixed with pesticides. Use caution when applying micronutrients through fertigation systems. Certain micronutrient blends may plug the emitters.

Table 2–15. Magnesium Management in Soil for Fruit Crops

Soil Magnesium* (ppm Mg)	Rating	Recommendation
Below 20	HR	Magnesium (Mg) should be applied for all crops. If pH is below 6.5, apply dolomitic limestone. At higher pH values, apply 30 kg soluble Mg/ha. Potash applications in excess of those recommended by soil test will increase the probability of magnesium deficiency.
20–39	MR	Magnesium is not required unless potassium (K) soil test is above 250 ppm. If soil test K is above 250 ppm and pH is below 6.5, apply dolomitic limestone. At higher pH values with K above 250 ppm, apply 30 kg soluble Mg/ha.
40–100	LR	If limestone is required, use dolomitic.
100+	NR	If limestone is required, either dolomitic or calcitic may be used.

HR = High response. MR = Medium response. LR = Low response. NR = No response to applied nutrient.

* 1 M ammonium acetate extract.

Foliar-applied nutrient uptake can be improved through the timing of the application and the use of surfactants. Younger leaves generally have a less well-developed cuticle and are able to take up more of the nutrient. Early morning applications may favour foliar uptake, and drought stress that results in a thicker cuticle may hinder uptake. Avoid the application of foliar nutrients during the heat of the day when leaves will dry quickly. Ensure good leaf coverage, particularly on the underside.

If a micronutrient is required, refer to Table 2–14. *Calcium, Magnesium and Micronutrient Sources*, page 20, and consult the manufacturer's label for information on rates, timing and recommendations to minimize injury.

Boron

Boron plays an important role in the structure of cell walls, fruit set and seed development, as well as protein and carbohydrate metabolism.

Boron deficiency is most likely to be found on alkaline soils or sandy knolls. Symptoms vary widely between crops. Apples may exhibit internal breakdown and premature drop of highly coloured fruit. Boron toxicity may occur when sensitive crops are planted in a rotation where boron has been applied or over-applied.

There is no OMAFRA-accredited boron soil test. Some soil test reports provide a soil boron value, however, soil levels are often less than 1 ppm, making it very difficult to get an accurate measurement. To correct deficiency, fertilizer manufacturers may mix boron sources with other fertilizers to be applied. Boron can also be foliar-applied for faster results.

Some crops are very sensitive to boron deficiencies. A soil pH between 5.0 and 7.0 provides the best conditions for boron uptake. Boron deficiencies are more likely to occur on soils with low organic matter and on exposed or eroded subsoils. Boron availability decreases during periods of drought.

Copper

Copper plays a role in chlorophyll production. It may also have a role in the suppression of some diseases.

Copper deficiency is rare on mineral soils, except perhaps very sandy soils.

Because soil tests for copper are unreliable, there is no OMAFRA-accredited copper soil test. Plant tissue analysis is a more useful tool.

Copper sulphate may injure leaves.

Iron

Iron is needed for chlorophyll formation, plant respiration and the formation of some proteins.

Iron deficiency, also called lime-induced chlorosis, is rare in Ontario. Symptoms appear on the young leaves first. Leaves turn yellow between the veins, but the veins will remain green except in extreme cases. Often symptoms are seen in only one area of the plant. Factors associated with iron deficiency include soils with high lime content (and therefore high pH), and gross imbalances with other micronutrients like molybdenum, copper or manganese.

An iron soil test does not correlate well with plant uptake or fertilizer response in Ontario. Consequently, there is no OMAFRA-accredited iron soil test. Plant analysis is a much more reliable indicator of iron availability. Iron deficiency is easily corrected with the foliar application of iron chelates, whereas soil application is not generally effective.

Manganese

Manganese is involved in photosynthesis and chlorophyll production. It helps activate enzymes involved in the distribution of growth regulators within the plant.

Manganese deficiency causes yellowing between veins of young leaves. Leaves gradually turn pale green with darker green next to the veins. Manganese toxicity can occur on soils with a low pH. It causes brown spots or yellow mottled areas near leaf tips and along the leaf margins and usually develops on older leaves. Brown spots may also develop on veins, petioles and stems.

The OMAFRA-accredited manganese soil test uses a manganese availability index. This index evaluates manganese availability based on soil manganese level and soil pH.

Soil-applied manganese may be useful in acidic, sandy soils. In soils with a pH greater than 6.5, soil-applied manganese will be unavailable to the plant. On alkaline soils, banded applications are often more effective than broadcast. Foliar-applied manganese is generally more effective where a manganese deficiency has been confirmed. If a deficiency is confirmed, apply foliar sprays when the plants are about one-third grown or sooner. Two or more sprays may be necessary at 10-day intervals.

Manganese availability is greatest at a soil pH of 5.0–6.5. It is important not to add more limestone than is needed to correct soil acidity. High organic matter levels decrease manganese availability. Foliar applications may be required for crops grown on muck soils.

Zinc

Zinc is important in early plant growth and in seed formation. It also plays a role in chlorophyll and carbohydrate production.

Zinc is relatively immobile within the plant. Deficiency symptoms appear first on younger leaves. Young leaves become mottled and show interveinal chlorosis, striping or banding. In advanced stages in tree fruits, small, narrow terminal leaves are arranged in whorls. This results in the typical "rosette" and "little leaf" description for zinc deficiency symptoms. Use leaf and soil analysis to test for zinc deficiency.

The OMAFRA-accredited zinc soil test is reported as a zinc index value, which estimates availability based on soil zinc level and soil pH. Zinc deficiency can be prevented by the application of zinc fertilizer to the soil at a rate of 4 kg of zinc/ha. Broadcasting up to 14 kg of zinc/ha will correct a deficiency for three years. No more than 4 kg zinc/ha should be banded. Early in the growing season, foliar sprays can be used to correct a deficiency after the symptoms have appeared.

Zinc deficiencies are most often seen on sandy soils with high pH levels. Heavily eroded knolls may also have deficiency problems. Large applications of phosphorus may aggravate zinc deficiencies. Livestock manure is often an excellent source of zinc.

Cover Crops and Building a Healthy Soil

A healthy fruit crop starts with a healthy soil. The key to success in building a healthy soil is effective management of the soil organic matter. Soil organic matter helps to maintain soil structure, enhances soil moisture-holding capacity, increases the soil's ability to hold nutrients and improves drainage. Maintaining adequate soil organic matter levels can help maintain crop yields, particularly in years of adverse weather.

Soil organic matter is made up of three parts: active, moderately stable and very stable. Growers can have the most influence on the active portion. The organic matter pool continually experiences gains and losses. If the addition of organic material to the soil exceeds the losses, organic matter levels increase. If the losses exceed the gains, organic matter levels will decrease. Increasing soil organic matter is a slow process, since only a small part of the organic matter added to the soil ends up as stable humus. It is therefore important to keep as much organic matter in the soil as possible by reducing soil erosion and eliminating unnecessary tillage passes. Organic matter additions are the most dependable way to increase total soil organic matter. These additions may be in the form of livestock manures, compost, forage crops or cover crops. Crop rotation prior to perennial fruit crop establishment plays a key role in maintaining soil organic matter.

Cover crops play a major role in soil management. They provide ground cover to reduce erosion and they add organic matter to improve or maintain the soil. There is growing interest in the use of cover crops for disease and pest suppression to replace or supplement chemical controls. Cover crops have a wide variety of suitable planting dates. Timely planting of cover crops will ensure the most soil improvement benefits from the cover crop investment. While broadcast application and incorporation of cover crop seed works well to establish cover crops, direct seeding or drilling will ensure faster and more even establishment.

Knowing what you want to achieve with a cover crop will help you select the best one for the job. See Table 2–16. *Selecting a Cover Crop*, page 24, and Table 2–17. *Characteristics of Cover Crops*, page 25. Cover crops can be divided into three groups based upon plant types: grasses, legumes and non-legume broadleaves.

Grasses

Grasses have fine, fibrous root systems that are well-suited to holding soil in place and improving soil structure. Grass species suitable for cover crops are fast-growing and relatively easy to kill (chemically, mechanically or by winter temperatures). Grasses do not fix nitrogen from the atmosphere, but they can scavenge large quantities of residual nitrogen left in the field after harvest. Wind strips are usually created from overwintering grass cover crops.

Spring cereals

Spring cereals are well-suited for late summer and early fall plantings. Under good growing conditions, spring cereals, like oats and barley, produce the greatest amount of crop biomass, and provide good ground cover. Once well-established, spring cereals are relatively tolerant of frost. Do not attempt to establish spring cereals later than mid-September, however, as the growth will be limited.

Winter cereals

Winter cereals are highly versatile cover crops. They can be planted in summer and will tiller and thicken due to their need for a cold treatment before flowering. Cereals such as winter wheat and rye can also be planted in fall for soil cover. Winter cereals generally overwinter well, providing winter and spring erosion protection. These grasses can be used to create spring wind barriers or residue mulch, or they can be killed early with herbicide to minimize residue cover at planting.

Warm-season grasses

Warm-season grasses like sorghum and millet are best suited for planting into the warmer soils of late June, July and early August. They are very sensitive to frost. Root growth is extensive and the top growth lush. Be prepared to mow these grasses to keep stalks tender and prevent heading. Do not mow closer than 15 cm to ensure regrowth. Nitrogen may be needed to achieve optimal growth.

Legumes

Legume cover crops can fix nitrogen from the air. They then supply nitrogen to the succeeding crop, protect the soil from erosion and add organic matter. The amount of nitrogen fixed varies depending upon species, stand density and the length of growth. Generally, more top growth indicates that more nitrogen is fixed. Ontario research has suggested that legume cover crops, such as red clover, are also effective at scavenging residual nitrogen from the soil.

Nitrogen release from legumes can be inconsistent. Account for this when calculating crop fertilizer needs. Excess nitrogen release late in the season could lead to excessive vegetative growth in fruit crops.

Some legume species, such as alfalfa or red clover, have aggressive tap roots that can break up subsoil compaction, but this requires more than one season's growth.

Non-legume broadleaves

These broadleaf crops cannot fix nitrogen out of the air but they may absorb large quantities from the soil. Growth will be poor if soil nitrogen levels are low or if compaction is severe. Most of these crops are not winter-hardy, so additional control measures are not normally required. Do not allow these crops to go to seed, as the volunteer seedlings can become a significant weed problem.

Cover crop mixtures

There is growing interest in cover crop mixtures from simple two-species mixes, such as oats and cover crop radish, to more complex mixtures. Mixtures support greater diversity and appear to achieve greater plant growth through synergy.

New and emerging cover crops

Every year new crops are evaluated as cover crops. Often these species are from different parts of the world and may not be well-adapted to Ontario growing conditions. For more information on new and well-known cover crop species, see the soil management section of the OMAFRA website at ontario.ca/crops or look at the regional pages and the Cover Crop Decision Tool from the Midwest Cover Crop Council at www.mccc.msu.edu.

Table 2–16. Selecting a Cover Crop

Function of the Cover Crop	Best Choice for Cover Crop
Nitrogen production	• Legumes — red clover, peas or vetch
Nitrogen scavenging	• Fall uptake — cover crop radish and other brassicas, oats • Winter/spring uptake — rye, winter wheat
Weed suppression	• Cover crop radish and other brassicas • Winter rye, sorghum sudan • Buckwheat
Nematode suppression[1]	• Mustard — Caliente, Cutlass, Forge • Sudans/sorghums — Sordan 79, Trudan 8 • Pearl millet — CFPM 101 • Marigold — Crackerjack, Creole • Oilseed radish – Adagio, Colonel
Soil structure building	• Grasses like oats, barley, rye, wheat, triticale, ryegrass • Fibrous root system plants such as red clover • Diverse cover crop mixtures
Compaction reduction	• Strong tap root plants that grow over time — Alfalfa, sweet clover
Biomass return to soil	• Fall — oats, oilseed radish, diverse cover crop mixtures • Summer – millets, sorghum sudan
Erosion protection (wind or water)	• Winter rye, winter wheat • Any well-established cover crop, e.g., ryegrass

[1] Nematode suppression is specific to the variety of cover crop, the species of nematode and the management of the cover crop materials.

Table 2–17. Characteristics of Cover Crops

Species	Seeding Rate (kg/ha)[1]	Seeding Time	Min. Germination Temp. °C (°F)	Nitrogen Fixed (F) or Scavenged (S)[2]	Overwintering Characteristics	Building Soil Structure	Weed Suppression	Nematode Rating[3] Lesion/Rootknot	Growth Rate/ Establishment	Root Type
Grasses										
Spring cereals	50–125	mid-Aug–Sept	9 (48)	S	killed by heavy frost	good	good	+/–	very fast	fibrous
Winter wheat	100–130	Sept–Oct	3 (38)	S	overwinters very well	good	good	+/nh	fast	fibrous
Winter rye	100–125	Sept–Oct	1 (34)	S	overwinters very well	very good	very good	+[4]/nh	very fast	fibrous
Sorghum sudan	30–50	Jun–Aug	18 (65)	S	killed by frost	good	good/fair	nh/–	very fast	coarse fibrous
Pearl millet	4–9	Jun–Aug	18 (65)	S	killed by frost	good	good/fair	nh/nh	fast	coarse fibrous
Ryegrass	12–18	Apr–May or Aug–early Sept	4.5 (40)	S	annual, Italian often survive; perennial overwinters	very good	fair/poor	–/–	slow	dense fibrous
Broadleaves – Legumes[5]										
Hairy vetch	20–30	Aug	15.6 (60)	F/S	overwinters	good	fair/poor	++/+	slow	tap with secondary fibrous
Red clover	8–10	Mar–Apr	5 (41)	F/S	overwinters	good	fair	++/+++	slow	weak tap/ fibrous
Sweet clover	8–10	Mar–Apr	5.5 (42)	F/S	overwinters	good	fair	–/–	slow	strong tap
Field peas	40–100	Jul–early Sept	5 (41)	F/S	killed by heavy frost	poor	good/fair	–/–	fast	weak tap/ fibrous
Broadleaves – Non-Legume										
Buckwheat	50–60	Jun–Aug	10 (50)	S	killed by first frost	poor	very good	+++/nh	fast	weak tap/ fibrous
Oilseed radish[6]	6–14	mid-Aug–early Sept	7 (45)	S	killed by heavy frost	fair	very good	–/–	fast	moderate tap
Other Brassicas[6], i.e., mustard, forage radish	varies with species	mid-Aug–early Sept	5–7 (41–45)	S	species dependent, many killed by heavy frost	fair	very good	–/–	fast	moderate tap

Nematode Rating Codes: – = Poor. + = Ability to host. nh = Non-hosts.

Cover crop seeding rates can vary greatly depending upon the goals for the cover crop, soil type and need or tolerance for crop residues.
1 100 kg/ha = 90 lb/ac.
2 Oilseed radish, buckwheat and the grasses do not fix nitrogen from the air but are scavengers of nitrogen from soil and manure applications.
3 Varietal differences in cover crop species may affect nematode reaction or lead to higher nematode populations. Proper variety selection is needed to ensure this cover crop is a non-host.
4 Rye whole-season rating would be higher.
5 Some diseases caused by *Pythium* and *Phytophthora* can be more severe after legume cover cropping.
6 Oilseed radish and other Brassica cover crops can be used as biofumigants when managed appropriately. The plant residues can be toxic or allelopathic to subsequent crops if the following crop is planted too closely after incorporation of the cover crop. Allow the cover crop residues to break down or desiccate before planting the next crop.